

ORIGINAL CONTRIBUTION

Alice C. Evans: Breaking Barriers

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Despite severe and persistent criticism of her research, Alice Evans persevered in her pioneering work on the bacterial contamination of milk, identifying the organism that caused undulant fever and demonstrating that drinking unpasteurized cow's milk could transmit the disease, undulant fever, to humans. The opprobrium that Alice Evans endured was unrelenting, even after her election as the first President of the Society of American Bacteriologists, (now the American Society for Microbiology), but she remained undeterred, a true heroine of American microbiology and a magnificent public health worker.

INTRODUCTION

"Every great advance in science has issued from a new audacity of imagination," John Dewey wrote in his 1929 book *The Quest for Certainty*. The American philosopher and educator might well have been referring to the achievements of Alice Catherine Evans, whose research into the bacterial contamination of milk identified the organism that caused undulant fever (also known as Malta fever) in humans [1]. In 1928, just a year before Dewey's words were published, Evans' findings resulted in her being elected the first female president of the Society of American Bacteriologists. Indeed, she personified "a new audacity of imagination" by challenging the wisdom of her scientific peers and pursuing her research despite the fact that her findings triggered enormous controversy in the medical and dairy communities.

Evans persevered in the face of her opponents, however, and found that drinking freshly drawn, unpasteurized cow's milk and handling infected animals could cause undulant fever [2]. Her seminal discovery in 1917 was that the *Micrococcus melitensis* organism prompting this illness in people was nearly identical to the *Bacillus abortus* bacteria causing spontaneous abortion, infertility, weight loss, and decreased milk production in cows and other ruminant animals. Evans' research, eventually reconfirmed many times over and accepted by physicians, scientists, and dairymen, resulted in the near-elimination of undulant fever through the mandatory pasteurization of milk in this country starting in the 1930s.

Her pioneering work has spared an untold numbers of lives and saved millions of dollars in public health costs. It also resulted in enormous savings to the

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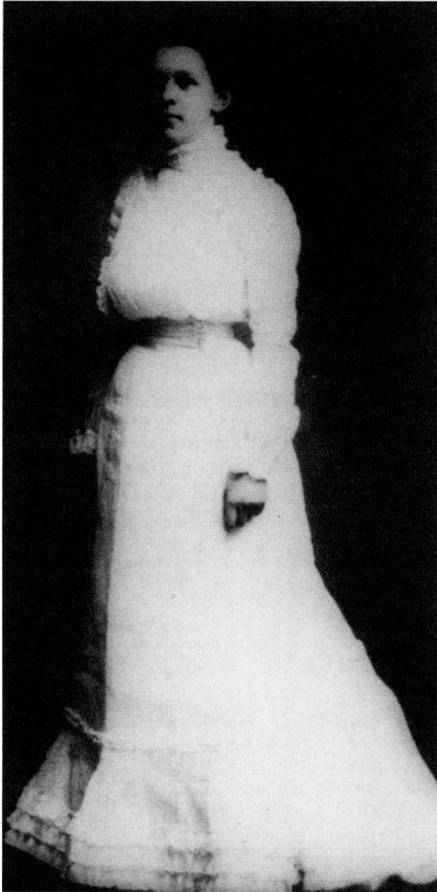


Figure 1. This photograph of Alice Evans was taken in 1928, the year she served as president of the Society of American Bacteriologists. (Photo courtesy of the National Library of Medicine.)

livestock and dairy industries, whose annual losses from aborted animals, lowered milk production, and reduced breeding efficiency have dropped from \$400 million in 1952 to less than \$1 million today [3]. Today Evans' discovery is recognized as one of the most important medical findings of the twentieth century and constitutes an important chapter in the history of infectious diseases.

The fruits of Evans' labor are also visible in the countryside of any dairy-producing region. In Maryland, for instance, each dairy barn that dots the landscape stands as a tribute to her work. Sanitation

standards enacted in the 1920s required barns for dairy herd owners to be as clean as kitchens, complete with concrete floors, plastered walls, new steel equipment, improved ventilation systems, and tight ceilings. Few people today even know about undulant fever, largely because Evans' work resulted in the disease being eradicated and, therefore, no longer a public health threat. The eve of a new millennium makes a fitting occasion to recall Evans' contributions to science and society during an era when the study of bacteriology was in its infancy.

Evans' presidency (Figure 1), besides being a personal accomplishment, also represented a benchmark for the Society of American Bacteriologists, which since 1961 has been called the American Society for Microbiology. Because her research transformed the dairy industry and, thus, improved public health, Evans' leadership reflected the degree to which the Society began playing a larger role in public policy in the United States after World War I. As president, she paved the way for other women to represent the organization. To date, eleven women have held that top position. The Society has also come a long way since 59 scientists gathered at Yale University in December 1899 to form the first independent organization devoted to promoting bacteriology in the United States. Today it numbers more than 40,000 members strong and remains the world's oldest and largest individual member life sciences organization.

Reflecting on Alice Evans' eventful life, her biography unfolds as a story of unending intellectual curiosity, independent spirit, and unflinching integrity. In placing her work in the context of her times, one can marvel at her accomplishments from three perspectives. First is her remarkable personal and professional journey, which took her from an upbringing in rural Pennsylvania to her college years at Cornell University and the University of Wisconsin, and then to the Department of Agriculture's Dairy Division. Her path

continued to the Public Health Service's Hygienic Laboratory, precursor to the National Institutes of Health, where Evans worked for most of her career until retiring as senior bacteriologist in 1945 [4].

A second perspective examines how society shaped her thoughts and actions as a scientist. Her gender, lack of a Ph.D., and government employment generated skepticism from many male contemporaries during the early 1900s. Loudest among her critics was Theobald Smith, one of the first scientists to discover that *B. abortus* could be found in fresh milk, who vociferously opposed Evans' premise that *B. abortus* was capable of causing illness in humans [5]. At one point he even refused to chair a committee on infectious abortion after learning that she would be a member. On the other hand, this same era presented singular opportunities for Evans and other researchers, as infectious diseases such as influenza came under greater scrutiny because of the expansion of laboratory techniques that accompanied the advent of modern medicine.

A third and final perspective views the ways in which Evans helped shape both the scientific community and society. Her groundbreaking research and the courage of her convictions in the face of opposition drew attention to threats to the food supply and the occupational hazards of farming. Thanks to her findings, by the late 1920s undulant fever was recognized around the world as a widespread and dangerous disease [4]. Unfortunately, Evans' work exacted a heavy personal toll on her. In 1922, she contracted undulant fever while conducting research and suffered from the disease's debilitating effects for more than twenty years.

Evans was the first woman to earn the University of Wisconsin's graduate scholarship in bacteriology and to hold a permanent post as a scientist at the Department of Agriculture's Dairy Division [4]. Continuing in this pathbreaking tradition, she became one of the most notable bacteriologists of her day, to the point that even

in retirement, she was sought after for advice by the medical and research community. She published scientific papers as late as 80 years of age; she once described herself as a "spry octogenarian" and gave frequent lectures on careers for women in science. Throughout her long life, until her death in 1975 at age 94, she worked to help open doors for many other female scientists.

AN EARLY LOVE OF LEARNING

Alice Evans was born on January 29, 1881, to a Welsh farming family (Figure 2) in Neath, Pennsylvania, a few miles from Scranton near the New York border. She was the younger of two children of Anne Evans, who had emigrated from Wales at age 14, and William Howell Evans, a surveyor, teacher, farmer, and former Civil War soldier [5]. She was educated at nearby rural schools, and a love of learning was instilled in her early in a home where politics, education, and religion were often discussed. Nonetheless, when she looked back later in life on her upbringing, Evans wrote of a certain restlessness. In her unpublished memoirs, she wrote that at first "dreams of going to college were shattered by lack of means." [6] She therefore started work as a schoolteacher, practically the only profession then available for women but grew bored after four years and looked for an escape.

She found it in the form of a two-year, tuition-free nature study course for rural schoolteachers at Cornell University's College of Agriculture. There, Evans immersed herself in subjects ranging from botany to meteorology. The program whetted her appetite for science so much that by the time it ended, she had lost all interest in receiving her certification. Instead, she later wrote, "I wanted to continue the study of science — any branch of biologic science would satisfy me" [6]. With the help of a scholarship and free tuition for out-of-state students, she completed her



Figure 2. Alice Evans poses with her family in front of their homestead in Neath, Pennsylvania. Left to right: her father, William, who was nicknamed “Professor”; her mother, Anne; Alice; and her older brother, Morgan. (Photo courtesy of the National Library of Medicine.)

bachelor’s degree, specializing in bacteriology because it was the only subject she could major in besides applied agriculture.

During her senior year, the door to her future career opened wider when she was awarded a graduate scholarship to study bacteriology at the University of Wisconsin’s College of Agriculture, where she pursued a master’s degree under professors who both dispensed good advice and excelled in their field. At the urging of E.G. Hastings, her advisor, she strengthened her knowledge of chemistry. Elmer V. McCollum, who taught her chemistry of nutrition class, would in 1913 announce his discovery of vitamin A.

It was at the end of her master’s program that Evans faced what would be a life-changing decision: continue graduate school and work toward a Ph.D., or accept a bacteriology research position at the Dairy Division of the U.S. Department of Agriculture’s Bureau of Animal Industry. Fatigued by the financial and physical strain of five years in college and realizing she was better suited to research than teaching, Evans, in 1910, opted for the job in bacteriology. Two additional factors

influenced her decision: the fact that back then a Ph.D. was not a prerequisite for scientific advancement, and the fact that she was neither interested in nor ready to pursue a doctorate in chemistry, the discipline her fellowship would have funded.

The position started at the Wisconsin campus, where Evans joined a team studying ways to improve the flavor of cheddar cheese, a research subject that made sense given the importance of the cheesemaking industry to that midwestern state. While at Wisconsin (Figure 3), Evans co-authored four papers with Hastings and E.B. Hart of the chemistry department, and she enjoyed the university community of Madison. Three years later, she relocated to Washington, D.C., where laboratory construction for the Dairy Division had just been completed.

Having heard from a fellow bacteriologist that the Division had no desire to hire female scientists, Evans mused on the train ride en route to D.C. that the absurdity of her situation did not seem funny. “I was on my way to Washington,” she wrote, “where I had not wanted to go and where I was not wanted.” Upon arriving in the

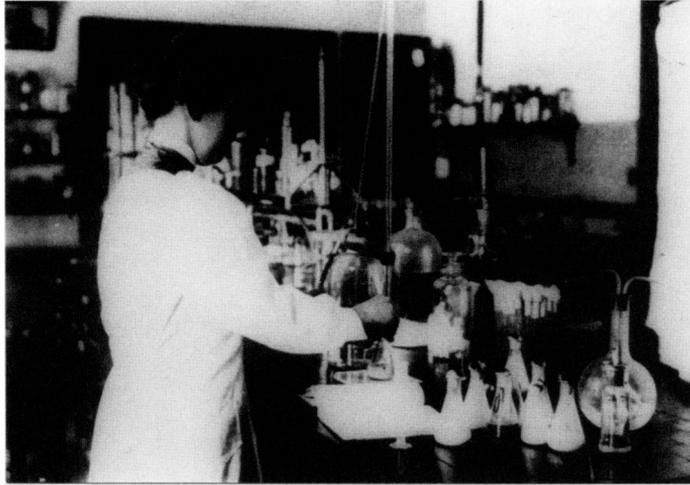


Figure 3. Alice Evans conducts research at the University of Wisconsin, 1912. (Photo courtesy of the National Library of Medicine.)

nation's capital on one of the hottest days of summer in 1913, Evans was relieved to find a warm welcome, despite the rumor that when her future colleagues found out that "A. Evans" was a woman, they almost fell off their chairs [6].

Evans was assigned to help look for ways that bacteria entered dairy products and to study the bacteria that existed in freshly drawn milk. The theory then was that freshly drawn "certified" milk was particularly nutritious and, therefore, healthy to drink. Evans found evidence to the contrary, after culture tests and animal experiments showed that *B. abortus* and *M. melitensis* organisms were closely related, enough so that the former, as well as the latter, could make humans ill [5]. Until then, scientists had always considered the two diseases completely separate. In her memoirs, Evans explained why bacteriologists had never noticed the resemblance before:

Bruce, the discoverer of the causal organism of undulant fever, considered it to be spherical, and placed it in the genus *Micrococcus* with other spherical species. But Bang, the discoverer of the causal organism of bovine contagious abortion, considered it to be rod-shaped, and he placed it in

the genus *Bacillus* with other rod-shaped species. It would be heresy in those days for a bacteriologist to think of a relationship between a *Micrococcus* and a *Bacillus*, but the fact was found to be that the morphology of the bacteria from the two sources is similar [6].

Presenting her findings at the 1917 annual meeting of the Society of American Bacteriologists, Evans posed the radical idea that humans could contract undulant fever by drinking raw milk. Her research was also published the following year in the *Journal of Infectious Diseases*. At the time, making this connection was considered medical blasphemy, and Evans set off a firestorm of protest and disbelief by physicians, veterinarians, dairy industry representatives, and other scientists. Immediately after her talk, fellow bacteriologists and physicians derided her evidence as meager and scoffed at the idea that the bacteria could cause symptoms in both animals and humans. In her memoirs, Evans wrote that the "reaction to my paper was almost universal skepticism, usually expressed by the remark that if these organisms were closely related, some other bacteriologist would have noted it" [6].

But Evans persevered in the face of hostility. She faced the wrath of dairy industry representatives, some of whom suspected her of collaborating with manufacturers of pasteurizing equipment. Certified dairy farmers who bristled at her findings lobbied tooth and nail against the extra costs of pasteurization, with a zeal exacerbated by the fact that her research affected the industry while it was fighting other problems, namely, the Bureau of Animal Industry's campaign of tuberculosis eradication in cattle. However, she remained a strong and unwavering advocate of pasteurizing milk until the practice became widespread in the United States.

Evans was later vindicated in her research as well. The first confirmation of her findings came in 1920 from San Francisco scientist Karl F. Meyer and his colleagues, and within four years, ten more investigators from seven other countries followed suit [6]. Also, Smith's further contention that cases of human infection were rare in regions with infected cattle was undercut by a key realization: specifically that in the 1920s and 1930s hundreds of cases of undulant fever were often misdiagnosed as influenza, malaria, tuberculosis, typhoid fever, or some other condition. And the year after her election to the Society of American Bacteriologists, her research reached a wide general audience in the September 1929 issue of *Ladies' Home Journal*, in an article by writer Paul deKruif titled "Before You Drink a Glass of Milk: The Story of a Woman's Discovery of a New Disease."

In a cruel irony, Evans contracted undulant fever in 1922 while conducting research, just as her findings began to be taken seriously. For her and other scientists of that era, catching diseases on the job was an occupational hazard. She suffered off and on from the agonizing disease for more than two decades, incapacitated for months at a time by the undulating waves of fever, pain, and drenching sweats for which the illness was named. Worse, many considered her health condition imaginary, a problem common to peo-

ple afflicted with the disease. "To be ill and regarded as an impostor is to be in an almost intolerable situation," she later wrote [6].

Evans missed the meeting at which she was elected Society president. She received the good news while at the Marine Hospital in Norfolk, Virginia, where she was recovering from yet another feverish episode. Her plight was not lost on the Society's members, who expressed pride "in a leader who has manifested not only intellectual leadership but also personal heroism of the highest order in the common warfare of mankind against its microbic enemies" [7]. Despite these hardships, Evans' sense of humor, perseverance, and concern for others served her well as she coped with her disease. She once commented wryly that it seemed as if "those bugs had a special animosity" for her since her discovery. She continued her research despite repeated bouts of ill health. Furthermore, she made a personal connection with others who had undulant fever, corresponding by letter to offer advice on treatment.

A LIFELONG SCIENTIFIC PIONEER

Throughout her life, Evans remained interested in applying her findings to current public health problems. In 1918, she joined the Public Health Service's Hygienic Laboratory where she conducted research on the influenza pandemic sweeping the globe and helped work to improve an antiserum used to treat epidemic meningitis, one of the worst diseases of World War I [2]. She also conducted important experimental work in infantile paralysis and sleeping sickness. For the last six years of her career, she studied immunity to streptococcal infections, adding to the knowledge and classification of the hemolytic streptococcal group. Evans wrote in her memoirs in 1963 that she thought she always drifted into the work for which she was best suited (Figure 4). She likened her career progression to



Figure 4. Alice Evans conducts laboratory research. (Photo courtesy of the National Library of Medicine.)

Emerson's observation that "Each man has his own vocation . . . there is one direction in which all space is open to him" [6].

In addition to her unusual scientific ability, Evans' career was shaped by opportunities that were a product of her time. She was fortunate in having her college costs covered by scholarships made available because the developing agricultural field needed leaders. Her first job as a bacteriologist was with the U.S. Department of Agriculture, the largest federal employer of female scientists during the 1920s and 1930s. Evans also benefitted from her association with Cornell University, one of the most important co-educational institutions for female scientists. And she was blessed with supportive and encouraging male mentors such as George W. McCoy, chief of the Hygienic Laboratory, who hired her as one of the laboratory's first women on the scientific staff.

In many other ways, Evans shaped the events of her day by breaking new ground for herself and other female scientists. Among the many awards and accolades she earned were election to the National Women's Hall of Fame; an honorary degree in medicine from the Woman's Medical College of Pennsylvania; and honorary doctorate of science degrees from Wilson College in Chambersburg, Pennsylvania, and the University of Wisconsin, her alma mater. Evans was also one of only two delegates from the United States to attend the First and Second International Congress for Microbiology, held in Paris in 1930 and London in 1936. In Paris, Robert E. Buchanan of Iowa State University was the only other American delegate, and Evans and Lydia Rabinowich of Russia were the only two female delegates.

Equally important, Evans helped women scientists to be taken seriously and lauded for their careful and accurate work at a time when they were often stereotyped into supporting and unheralded roles. She showed an interest in young people and minorities, as evidenced by her establishment of a tuition fellowship at Federal City College in Washington, D.C., now the University of the District of Columbia, set up through the local branch of the American Association of University Women. Today, the American Society for Microbiology continues to honor her with its annual Alice C. Evans Award, given since 1983 to those who have made major contributions toward women's full participation in microbiology [6]. The 1999 awardee was Ruth Kirschstein, Deputy Director of the National Institutes of Health and former Director of the National Institute of General Medical Sciences, where over her long career she, like Evans, has been a strong proponent of women in science.

Historian Margaret Rossiter wrote that as one of the foremost female scientists in the federal government, Evans was a great credit to the agencies where she worked and exemplified "a career in government service at its best" [8]. Evans, who helped

establish a precedent for future employment of women in federal health agencies, was truly a revolutionary in her own time, for which scientists and laypersons alike are enormously grateful. By persevering in her research in the face of widespread criticism, she calls to mind the words of Louis Pasteur, the father of microbiology and a champion of rigorous scientific inquiry. Pasteur urged colleagues to “worship the spirit of criticism,” for without it, he said, “everything is fallible.” That “spirit of criticism” was very much a part of Alice Evans’ life and work. She endured non-stop scrutiny before becoming vindicated in her findings, and only then was she able to take satisfaction in the knowledge that she was right after all — even though her efforts exacted an enormous toll on her own health.

By the end of her eventful life, Evans had earned enormous respect for her research on undulant fever, had become a major catalyst in the mandatory pasteurization of milk, and had broken new ground as the first woman to head the Society of American Bacteriologists. It is important to remember, though, that her professional success came at the price of considerable criticism, as well as decades of suffering from the chronic and debilitating illness whose study formed the central element of her life’s work. Evans downplayed any hardships she endured, writing in her memoirs that “the course that was open for my ship to sail was on the whole gratifying. The going was rough at times,” she acknowledged, but added that “there were stretches of clear sailing too.”

Her fellow bacteriologists were more openly appreciative of her sacrifice when, more than seventy years ago, they gathered to honor one woman whose findings dramatically advanced their field of research and improved public health in this country. In a small way, today’s members of the scientific community can each do the same. The next time you pour yourself a glass of milk, raise a toast to Alice Catherine Evans.

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REFERENCES

1. Colon, D.M. Alice Catherine Evans (1881-1975). In: Grinstein, L.S., Biermann, C.A., and Rose, R.K., eds. *Women in the Biological Sciences: A Bibliographic Sourcebook*. Westport, Connecticut: Greenwood Press; 1997, pp. 163-169.
2. Porter, R., ed. *The Biographical Dictionary of Scientists, Second edition*. New York: Oxford University Press; 1994, p. 217.
3. USDA APHIS Veterinary Services website. Facts about Brucellosis. <<http://www.aphis.usda.gov/oa/brufacts.html>>
4. Kleinman, S.S. Alice Catherine Evans (1881-1975), Bacteriologist. In: Shearer, B.F., and Shearer, B.S., eds. *Notable Women in the Life Sciences: A Biographical Dictionary*. Westport, Conn: Greenwood Press; 1996, pp. 117-122.
5. O’Hern, E.M. Alice Catherine Evans. In: *Profiles of Pioneer Women Scientists*. Washington, D.C.: Acropolis Books Ltd.; 1985, pp. 126-138.
6. Alice C. Evans. *Memoirs* (unpublished). Washington, D.C.; 1963.
7. Society of American Bacteriologists. Minutes of business meeting, December 30, 1927; p. 1.
8. Rossiter, M.W. Government Employment: Paper Reforms but Expanded Segregation. In: *Women Scientists in America: Struggles and Strategies to 1940*. Baltimore: The Johns Hopkins University Press; 1982, pp. 218-247.